EXHIBIT C

Site: **Inmarsat**
40 Melton St.
London NW1 2EQ
England

Date Visited: June 23, 1992

Report Author: B. Edelson

ATTENDEES

NASA/NSF:

W. Brandon
B. Edelson
J. Pelton
L. Riley

HOSTS:

Eugene Jilg

Director, Satellite Programmes Division

Jai P. Singh

General Manager, Project 21

Robert E. Levey

Sr. Market Analyst, Maritime Business Planning

Eugene I. Staffa

Sr. Commercial Advisor, Land Mobile
and Special Services

Rainer J. Kroll

AES Engineer, Aeronautical Engineering

Howard Feldman

Project Leader, Maritime System Development

Neil Teller

Manager, Inmarsat-C System

BACKGROUND

The International Maritime Satellite Organization (Inmarsat) was formed in 1979 to provide satellite communications to ships at sea. It now provides service to all types of mobile users. There are currently 67 members (owners) of Inmarsat, the United States having the largest investment share, about 23%; the United Kingdom and Norway are next with 11% and 10.5%, respectively. Annual system revenues have grown from $18 million in 1982 to $292 million in 1992. Traffic and revenues are increasing at rates of 35 to 40% per year. There are now some 23,000 users of the system, 25% of them operating on land.

The Inmarsat system consists of three components: (1) the space segment and its support structure; (2) gateway earth stations for maritime, land, and aeronautical mobile satellite services (respectively MMSS, LMSS and AMSS); and (3) mobile terminals of various classes suitable for operation on all kinds of vehicles.

Satellites

The first series of satellites used by Inmarsat, starting in 1982, was leased from several sources: COMSAT (MARISAT), ESA (MARECS), and INTELSAT (ISV-MCP), MARISAT and MARECS being precursor demonstration services and the MCP being a maritime communications package on some INTELSAT Vs. The Inmarsat II series now in service was introduced in 1990. The Inmarsat III series is currently under procurement from GE Astro and Matra-Marconi with initial launch scheduled for 1994. Inmarsat envisions a fourth series of advanced satellites coming into service late in this decade.

Table Inmarsat.1 shows the evolution of the four series of satellites.

Figure Inmarsat.1 shows the present global system coverage with four Inmarsat II satellites.

Mobile Terminals

Inmarsat supports five categories of mobile terminals, three of which are in commercial use now and two are to be introduced in the next year. All work through the Inmarsat II satellites and provide voice, fax, telex and data service at various levels. The characteristics of the five terminals are shown in Table Inmarsat.2.

Inmarsat-A terminals have been in service since 1978 (before Inmarsat was formed). As of April 1993 there were about 14,770 shipboard and 6,000 land-based A-terminals. These terminals provide analog voice, telex, and data services. Inmarsat-B is an all-digital version of Inmarsat-A, to be introduced in 1993. Inmarsat-M, under development, is to be an advanced technology, smaller, lower cost all-digital terminal also to be introduced in 1993.

Inmarsat-C, which provides low bit rate data service, entered service in 1991 to satisfy the need for a very small, lightweight terminal. As of April 1993, there were about 3,900 Inmarsat-C terminals at sea and 2,000 in LMSS. These terminals are expected to be widely used for many applications including safety and distress as well as business communications for ship and land craft of all sizes.

The aeronautical terminal has been developed and entered service to serve commercial and

corporate aircraft for air traffic control, operational communications, and public services (AMSS). Having started service in 1992, about 200 aeronautical terminals were in operational use on corporate aircraft and airlines by April of 1993. The numbers are expected to pass 1,000 in 1994 and grow strongly thereafter.

Table Inmarsat.1
Satellite System Evolution

Generation	1*	2	3	4
Capacity Channels	50	250	1500	25,000+
Power (EIRP)	33-35 dBW	39 dBW	48 dBW	60 + dBW
Features	GEO, Global beam, leased	GEO, Global beam	GEO, Global and spot beams	GEO + Possible lower earth orbits
Year of Operation	1982	1992	1995	1998

Table Inmarsat.2
Mobile Earth Stations

PARAMETER	Inmarsat-A	Inmarsat-B	Inmarsat-C	Inmarsat-M	Aeronautical
Steering	Steerable	Steerable		Steerable AZ only	Electronic
Type	Parabolic	Parabolic	Omni	Linear array	Phased array
EIRP	36 dBW	25-33 dBW	12 dBW min at 5°	22-28 dBW	14 dBW l-g 26 dBW h-g
Receive G/T	-4 dB/K min	-4 dB/K	-23 dB/K at 5°	-12 dB/K	-26 dBK l-g -13 dBK h-g
Telex & Data Rates	50 baud telex	50 baud telex 9.6 kbps	600 bps	2.4 kbps	600, 1200, 2400, 10,500 bps
Telephony	FM	Digital coded	Data only	Digital coded	Digital coded
Voice Coding Rates	12 kHz deviation	16 kbps		4.2 kbps	9.6 kbps
Channel Spacing	50 kHz	20 kHz	5 kHz	10 kHz	5 kHz, 17.5 kHz

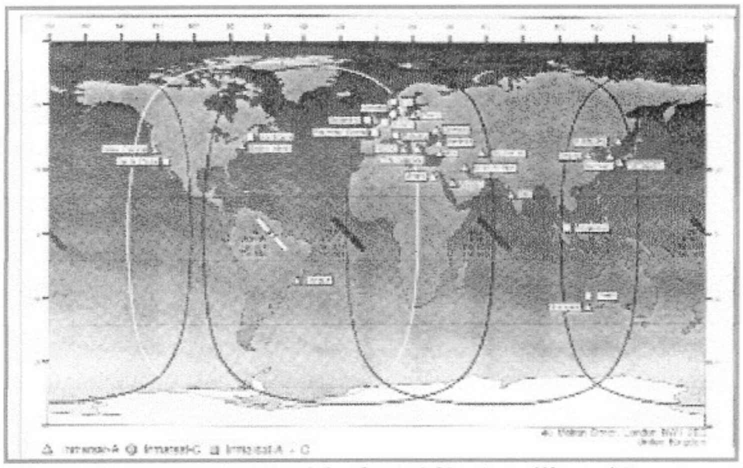

Figure Inmarsat.1. World of Mobile Satellites (Courtesy Inmarsat)

TECHNOLOGY AND DEVELOPMENT

Although Inmarsat does not conduct a large R&D program, it has been aggressive in expanding its role from providing maritime services to all types of mobile services, and has been innovative in introducing new technology and equipment into its system. Inmarsat has been a pioneer in fostering the use of L-band for satellite communications and has supported many advanced developments in satellites, mobile terminals, and transmission systems. Three projects illustrate the character and level of Inmarsat's introduction of advanced technologies into its system: (1) Inmarsat III satellites; (2) mobile digital terminals; and (3) Project 21. In Project 21, Inmarsat is studying possibilities for the use of hand-held PCS terminals operating through more powerful satellites near the end of this decade.

Inmarsat III Satellite

The Inmarsat III satellite, currently being developed and built under contract to GE Astro Space (U.S.) and Matra-Marconi Space (UK), will incorporate several advanced technologies. This new generation of satellites promises to provide far greater capabilities and capacity, providing a wider group of services with higher performance than Inmarsat II and the previous series of leased spacecraft. These satellites will each have five spot beams (48 dBw), thus allowing multiple frequency reuse, plus a global beam (39 dBw). They will have greater bandwidth (the full ITU allocation of 30 MHz) and an increase in capacity to 1,500 channels (a 6-fold increase over Inmarsat II). Each satellite will also have a navigation and SAR package. The development and production budget for Inmarsat III is about $750 million for four satellites, four launchers, infrastructure and support.

Major technologies introduced in the Inmarsat III satellite include:

1. An advanced multibeam antenna system and feed network,
2. 6 x 6 matrix switch,
3. High-density light-weight L-band communications package using advanced MMIC technology,
4. 20 watt SSPA with high gain and phase stability, and
5. light weight LNR and highly stabilized frequency synthesizer.

Inmarsat required Matra-Marconi to perform a technology verification program on all key technologies before the final contract award. Also, before starting on flight units, Matra-Marconi will build an engineering model of the complete Inmarsat III communications system. These two steps, unusual in space system development nowadays, are expected to be effective in eliminating design errors before they become costly, and allow the establishment of a firm production and launch schedule once the design has been proven. They represent good engineering practice, incorporating lessons learned from previous programs.

Mobile Digital Terminals

With only a small R&D budget, Inmarsat has nevertheless been able to stimulate the development of advanced technologies and have these incorporated into improved land, sea and airborne terminals by promoting digital technology, setting tough standards, establishing a rigorous test program, developing new service offerings, and, above all, creating a large market.

The new high technology terminals recently introduced or currently under development add

major new capabilities to the Inmarsat system. They are designed to match the capabilities of the Inmarsat III satellites, and they represent an excellent use of advanced digital and microwave technologies in the terminals themselves and in the all-digital transmission systems that they will utilize. For example, the Inmarsat-M terminal introduced in 1993 is half the size and cost of the A terminals now in widespread use. It uses only 10 kHz for a voice channel (1/5 the bandwidth used by Inmarsat-A) and can be counted on to be the mainstay of maritime and mobile services in the future.

The terminals will be manufactured by ten or more companies from several countries. This competition for what is expected to be a very large world market, over 50,000 for MMSS and over 25,000 for LMSS by the year 2000, will insure good engineering and use of the best state-of-the-art technologies. Moreover, continuous improvement with the introduction of new technologies over the years will undoubtedly make the system even more efficient.

Project 21

Inmarsat has initiated a far-reaching effort known as Project 21 to develop and introduce a range of technologies and systems leading to personal mobile satellite communications, "the ability to communicate instantly and effortlessly to and from anywhere on earth." The goal is to provide a capability to communicate through a satellite with a hand-held phone before the end of the decade.

Noting the 15 million worldwide cellular phone users today, Inmarsat predicts a growth to 400 million users by the year 2000, a $100 billion per year industry providing cellular, paging, private mobile and personal communications. In this market it is foreseen that satellites can contribute in several ways to supplement local cellular service to international travellers, users in cellular gaps or remote areas, small boats and aircraft. Also, personal satellite communications should have many applications for developing countries.

The hand-held satellite phone, to be known as Inmarsat-P, will be developed to provide a voice service quality similar to that of a cellular system. In addition to duplex voice, it should provide fax, paging, location and data services. It will be designed to weigh less than 750 grams, require a power output of less than one watt, and cost less than $1,500. The phone will be switchable between terrestrial cellular and satellite functions.

In order to serve such small terminals as Inmarsat-P, the generation of spacecraft after Inmarsat III would have to be extremely powerful. Toward that end, a number of system studies are being conducted on several options: (1) a GEO satellite system with more powerful spacecraft and very-large-aperture antennas; (2) a LEO system; (3) an intermediate circular orbit system; and (4) a combination of GEO and non-GEO constellations interconnected by ISLs.

Several member organizations and companies, such as COMSAT, British Telecom, KDD (Japan), and Telespazio (Italy), are working with Inmarsat to conduct technology, economic, and system studies on the Inmarsat-P system.

SUMMARY

Inmarsat is an international satellite communications system that currently provides voice and

data services to over 25,000 mobile users on ships, land vehicles, and aircraft. Traffic and revenues are increasing rapidly and over 400,000 users are projected in the next six to eight years.

Although Inmarsat has a very small R&D budget, it has effectively incorporated technology developed by its members and by other organizations into its satellites and terminals. It has been aggressive in expanding its role from maritime service to all types of mobile platforms and innovative in introducing new service offerings.

The Inmarsat III satellites now under construction will represent a major technological advance and provide six times the capacity of the Inmarsat II satellites currently in service. The Inmarsat-A terminals which have been providing analog voice service for more than a decade are being replaced and supplemented by a number of all-digital voice and data terminals tailored for use on land and aircraft as well as ships.

Inmarsat is working toward developing a system involving more powerful large satellites, and possibly a constellation of smaller LEO or intermediate orbit satellites, to provide a global PCS using hand-held instruments by the year 2000.

Published: July 1993; *WTEC Hyper-Librarian*